We2F-3

200 GHz-band Low-loss Half-Mode SIW CMOS Interconnects and Transmission Lines for Sub-Terahertz Frequency Band Applications

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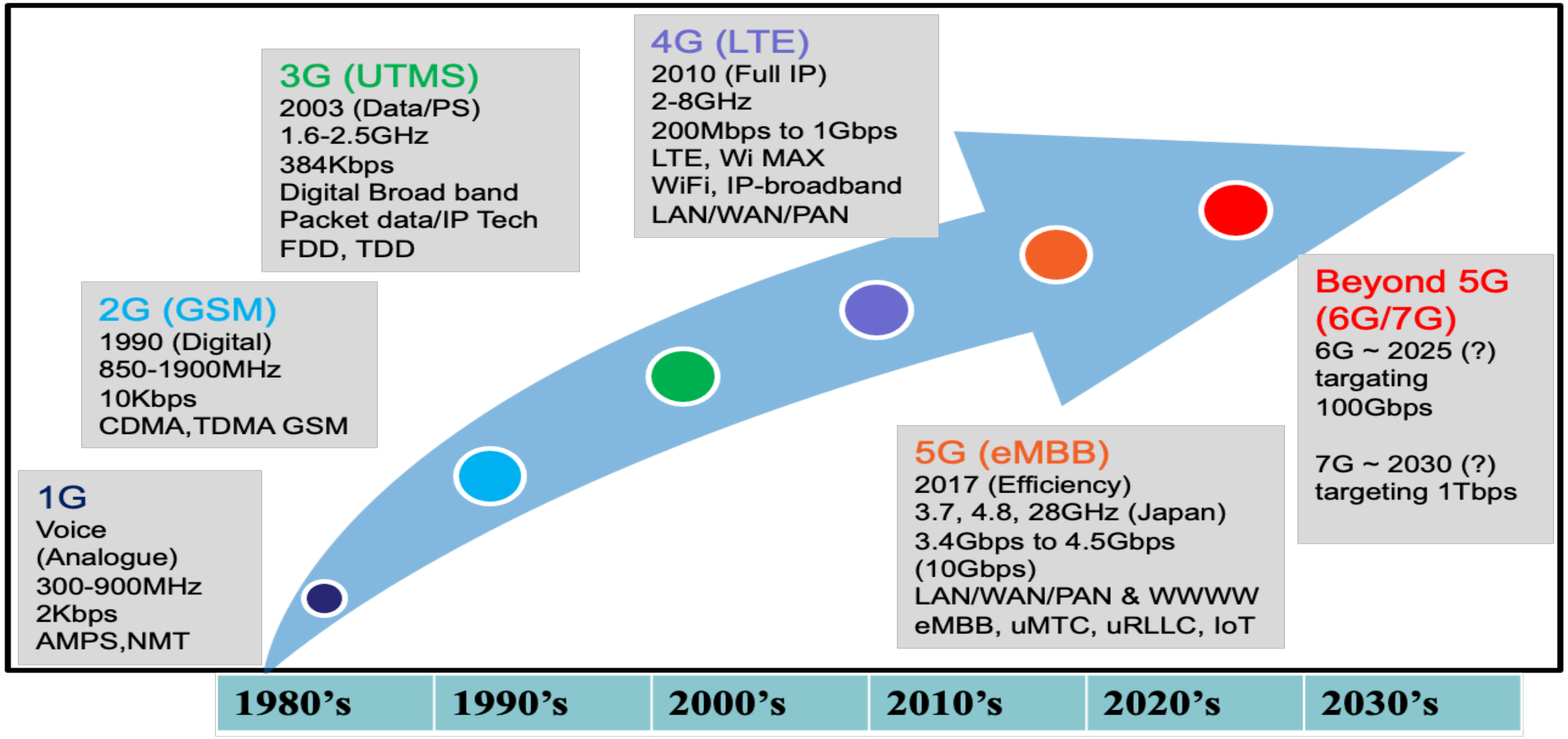
Outline

- ❑Background Introduction
- ❑Sub-Terahertz SIW Design
  - ➢ Substrate Integrated Waveguide
  - ➢ CSRR Loaded HMSIW Interconnect Design
  - ➢ Measurements Results
- ❑Summary

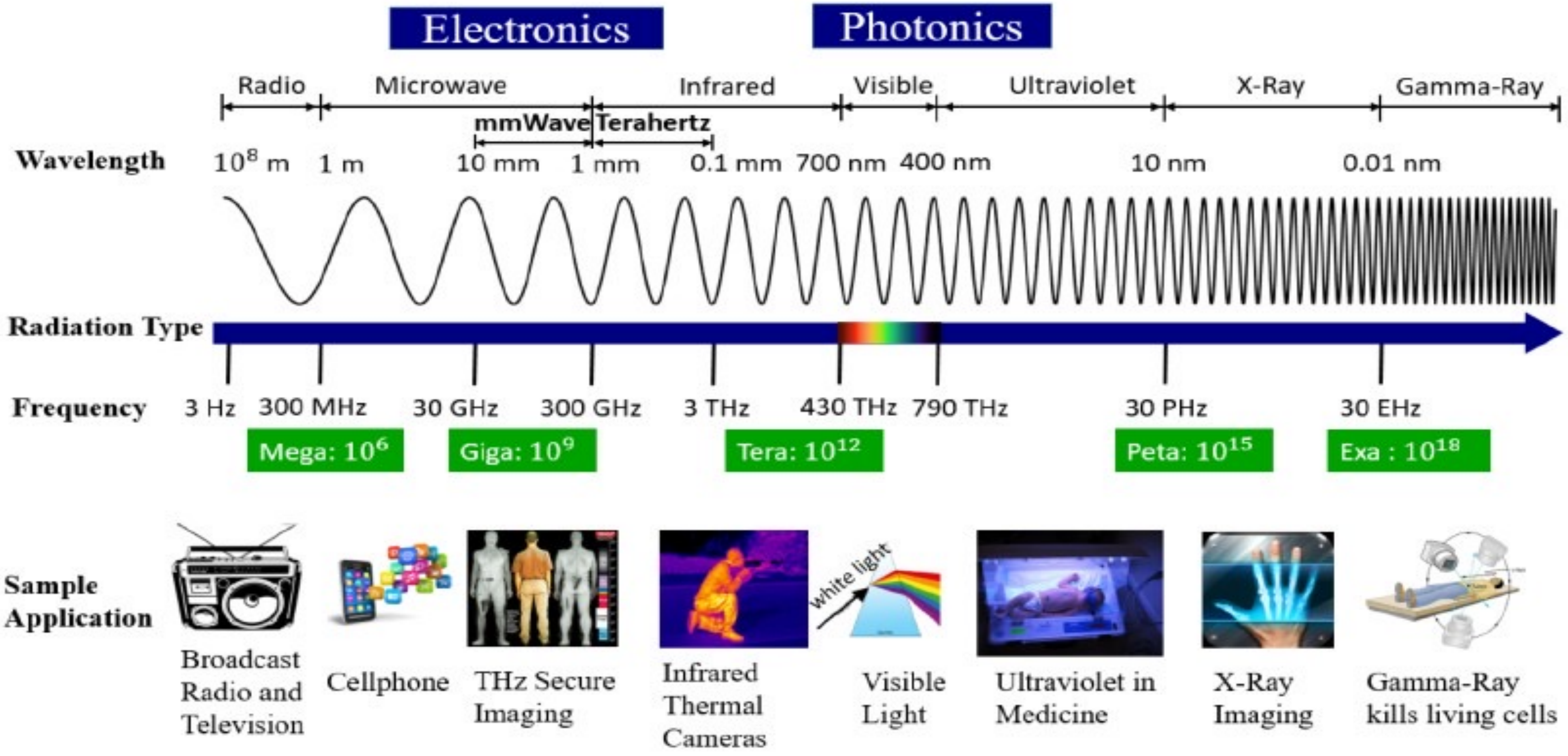
Introduction



Increase in high-volume telecommunications
⇒ Explosive increase in data traffic volume

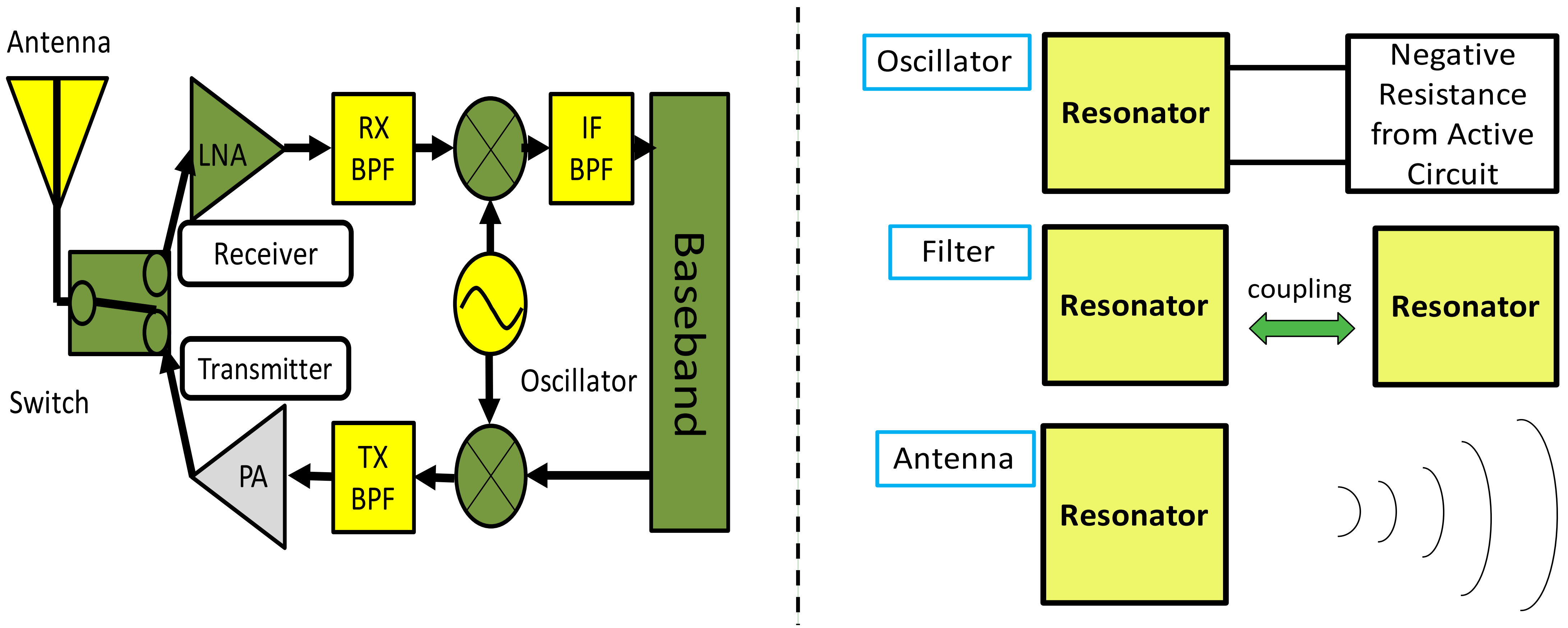
Frequency Band and its Application

Vision: Above 100 GHz



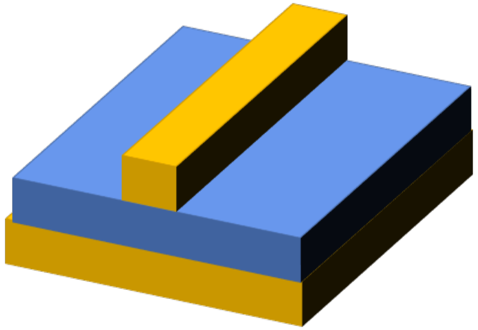
[1] T. S. Rappaport, Y. Xing, O. Kanhere, S. Ju, A. Alkhateeb, G. C. Trichopoulos, A. Madanayake, S. Mandal, "Wireless Communications and Applications Above 100 GHz: Opportunities and Challenges for 6G and Beyond (Invited)," IEEE ACCESS, submitted Feb. 2019.

Resonators in Wireless Communication

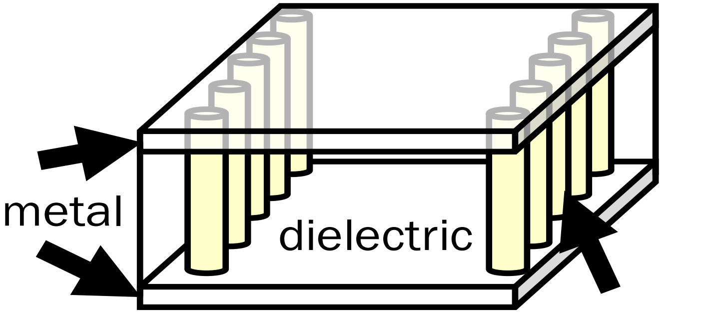


Resonators play an important role in wireless communications

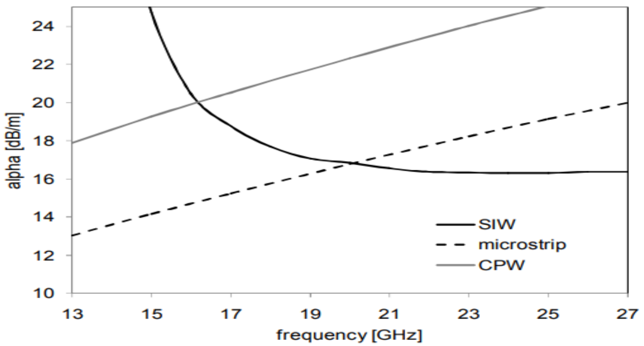
Substrate Integrated Waveguide (SIW)



Conventional Microstrip Line



SIW



Comparison of SIW with other transmission lines

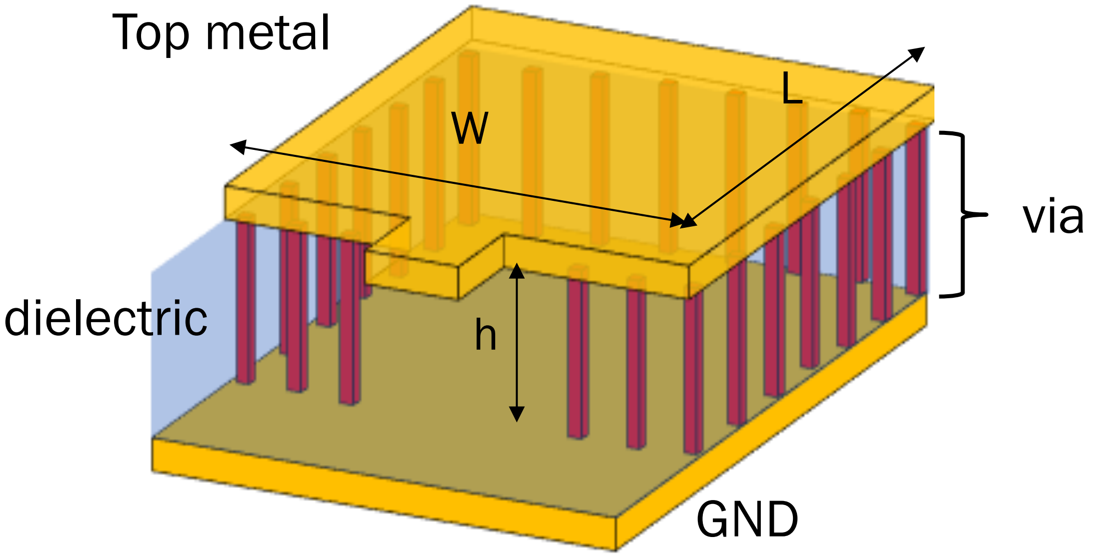
- Performance varies with metal thickness.
- Radiation loss increases at higher frequencies. → wavelength becomes very small.

- Signal propagates reflecting inside the dielectric, → thickness of the metal is irrelevant.
- Low radiation loss due to confinement and propagation within metal walls

SIW has lower attenuation than conventional transmission lines

[Ref] M. Bozzi, L. Perregrini, and Ke Wu, "Modeling of losses in substrate integrated waveguide by Boundary Integral-Resonant Mode Expansion method," in *2008 IEEE MTT-S International Microwave Symposium Digest*, Atlanta, GA, USA, 2008, pp. 515–518.

SIW Cavity Resonator

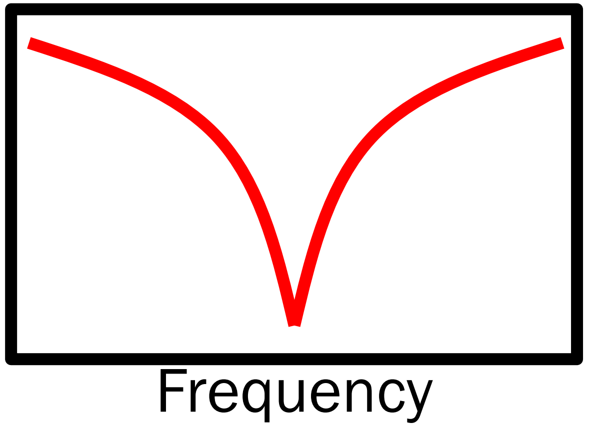


Full-Mode SIW

Resonant frequency of TE_pqr mode **:**

$$f_{0_{TE_{pqr}}} = \frac{1}{2\pi\sqrt{\varepsilon\mu}}\sqrt{\left(\frac{p\pi}{L}\right)^2 + \left(\frac{q\pi}{h}\right)^2 + \left(\frac{r\pi}{W}\right)^2}$$

- Resonant at limited TE mode frequencies
- Operates as a resonator with low unwanted radiation with unique cutoff frequency
- Easy to realize with planar circuits
- Occupies a large area



Background Summary

Background

- Expectations for high-frequency devices capable of supporting increasingly sophisticated wireless communications
- Low-loss circuits using SIW technology

Problem

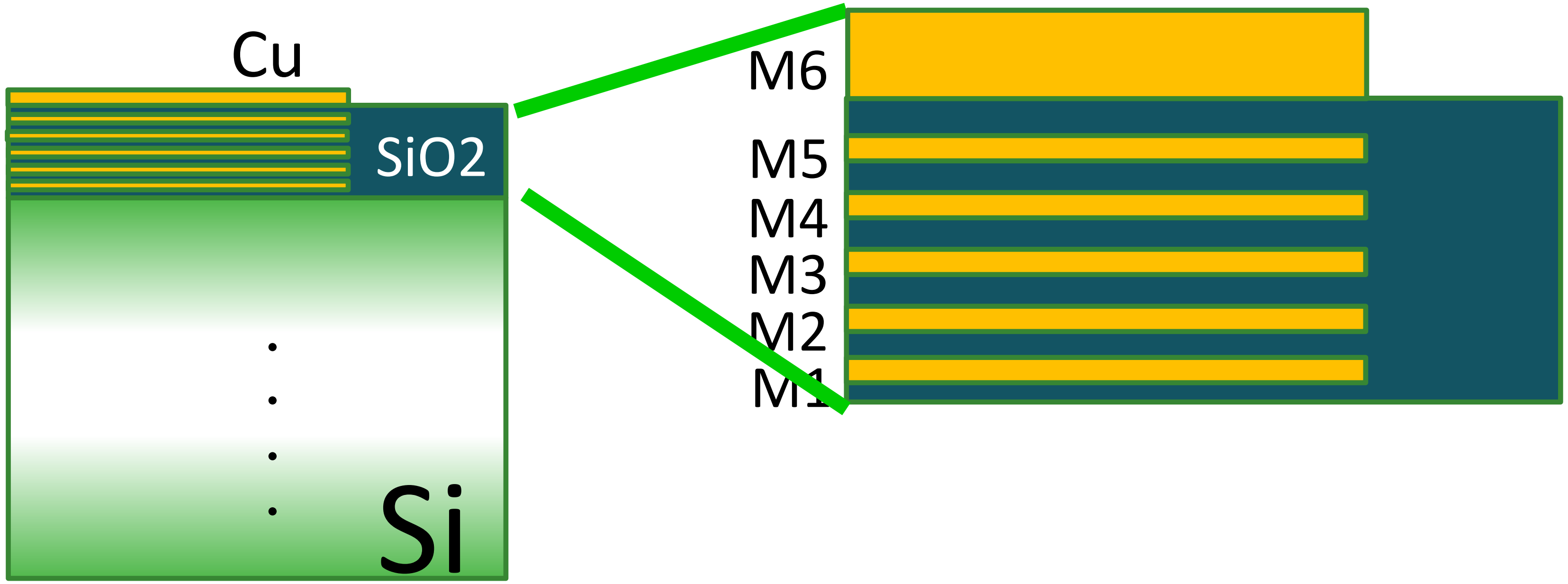
SIW circuits require extensive occupancy area

⇩

Target

Miniaturization of high-frequency SIW circuits using CMOS
→Leads to realization of high performance and compact high-frequency circuits

Process Used → Commercial 1P6M CMOS



Advantage

Low cost compared to modern processes

Disadvantage

Poor performance in the high-frequency band

SIW Miniaturization Techniques

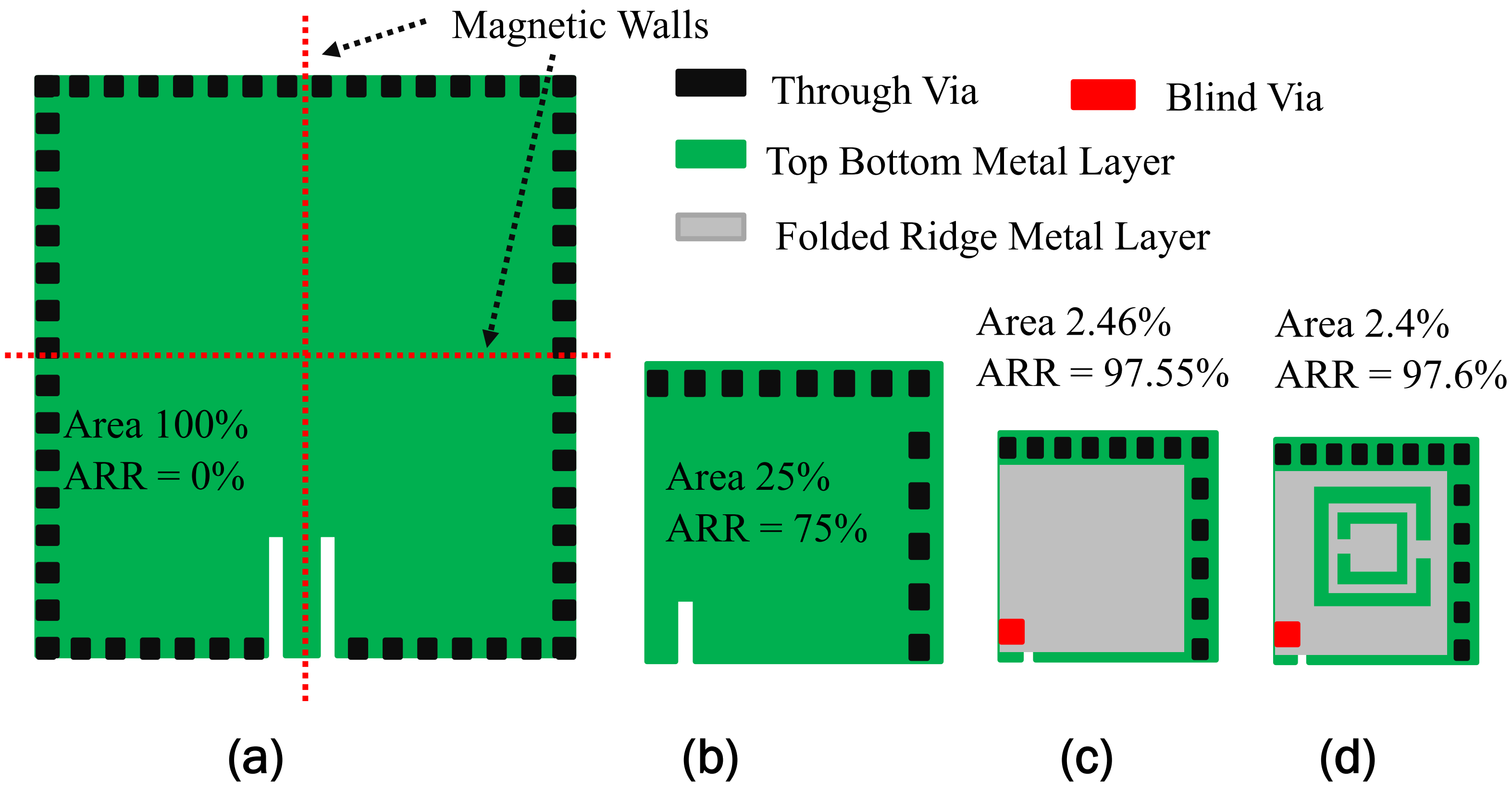
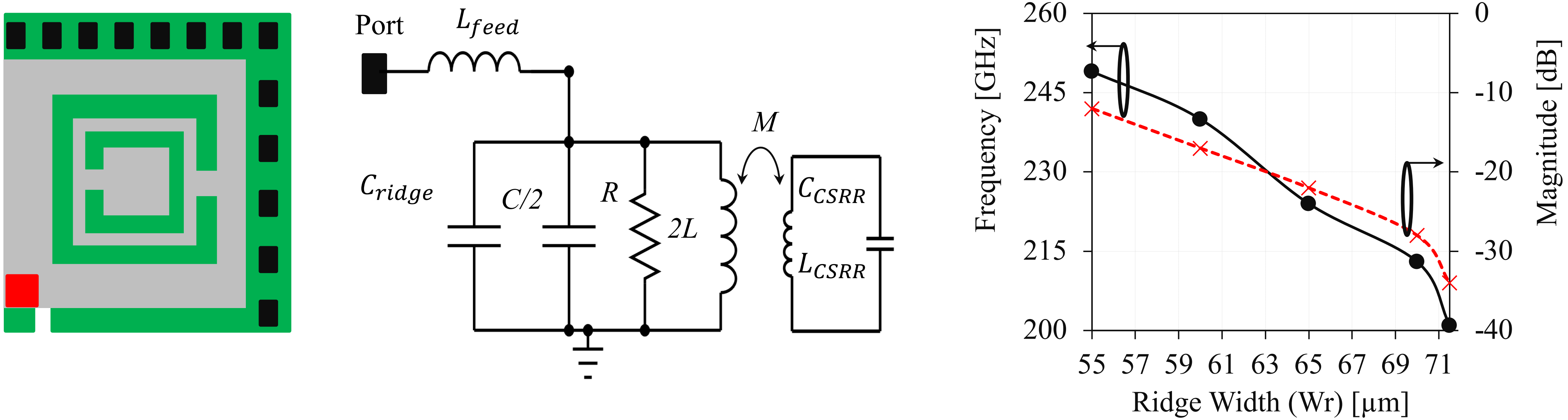


Fig. SIW cavity: (a) standard mode; (b) QMSIW; (c) folded ridge QMSIW; (d) folded ridge QMSIW with CSRR loadings. *ARR = Area Reduction Ratio compared to standard SIW at the same resonance.

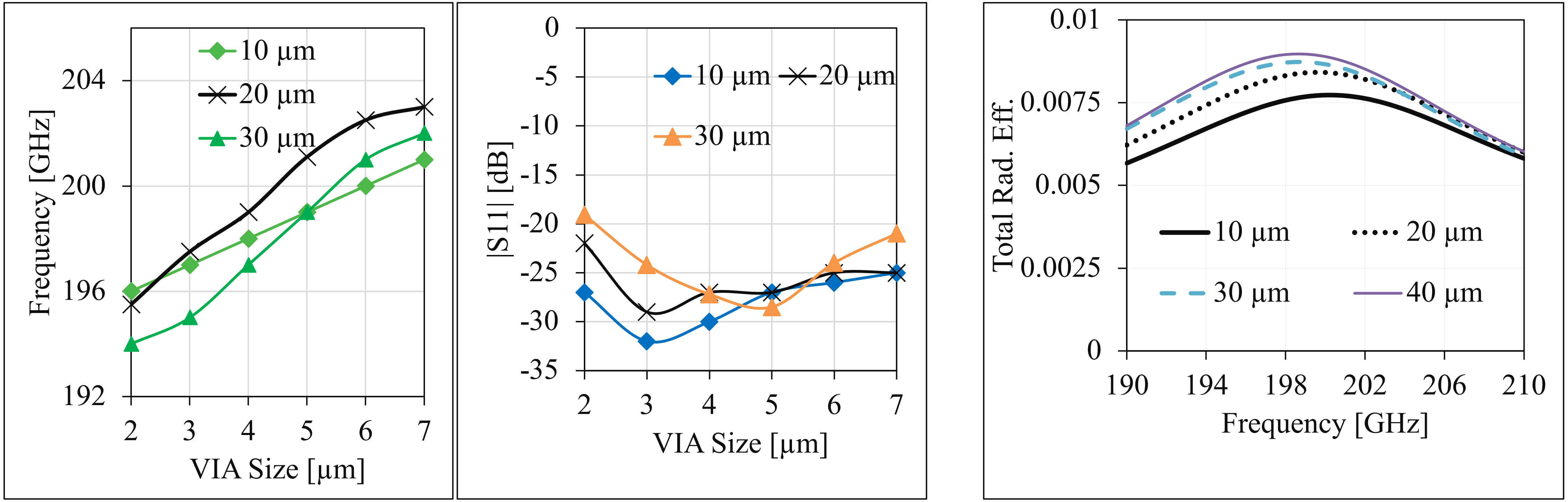
SIW Miniaturization Techniques



(a) (b) (c)

Fig. (a) Folded ridge QMSIW with CSRR loadings, (b) Equivalent Circuit, and (c) Variations of resonance frequency and return loss magnitude with varying ridge width.

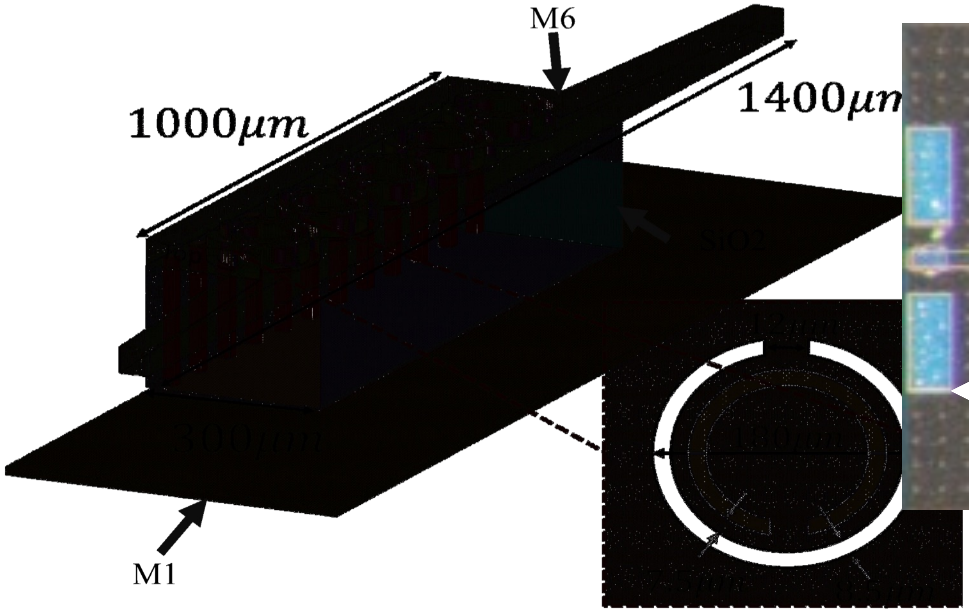
VIAS effect in the Cavity Design



(a) (b) (c)

Fig. Effect of square via size (side length) and via spacing of folded ridge QMSIW cavity on: (a) resonance frequency; (b) reflection coefficient; (c) Total radiation efficiency of folded ridge QMSIW cavity with CSRR loading with varying via spacing.

Fabrication Layout of the Proposed Cavity Resonator



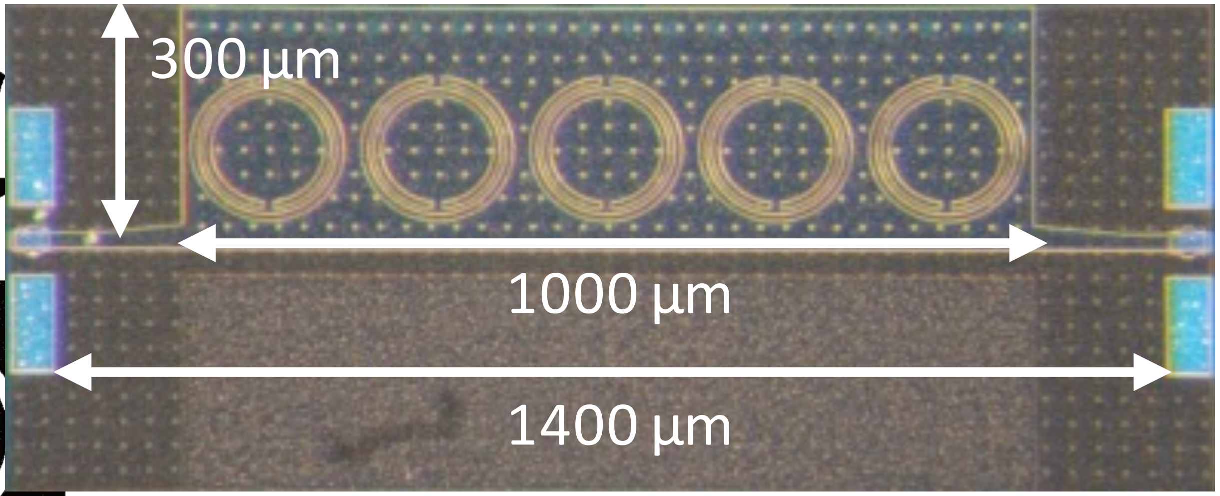
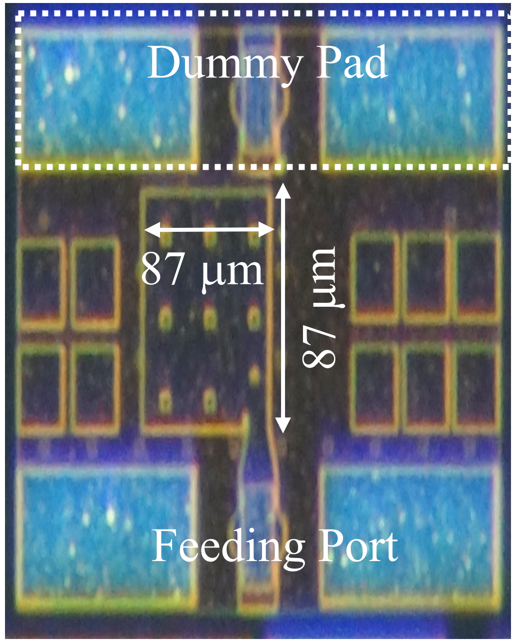
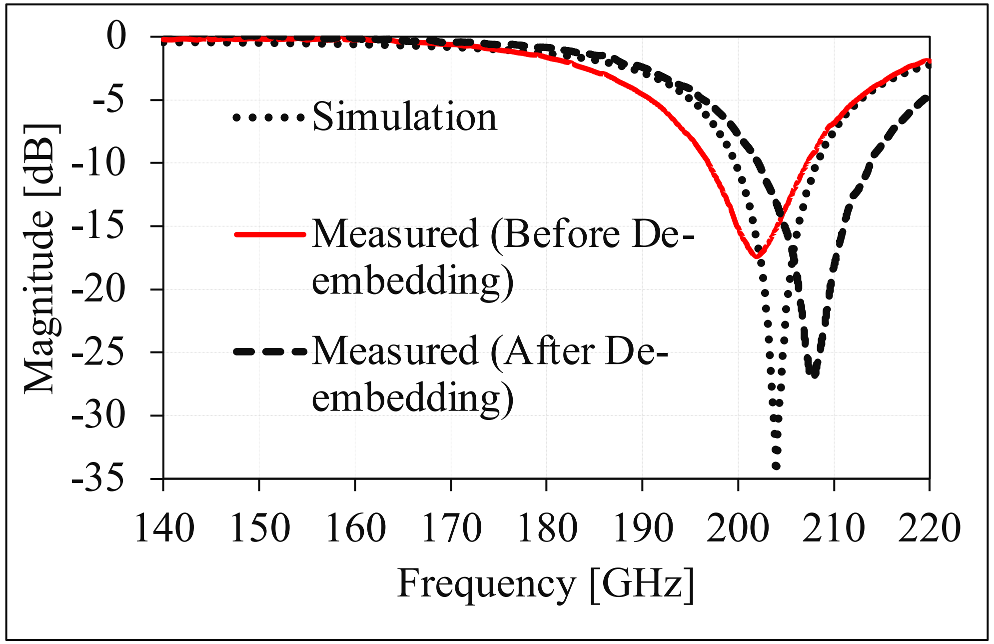


Fig. a. Proposed SIW Cavity Resonator Micrograph of fabricated prototype. EM model of the proposed folded ridge QMSIW cavity. (a) 3D view; (b) top view; (c) side view

Fabrication Layout of the Proposed Cavity Resonator



(a)



(b)

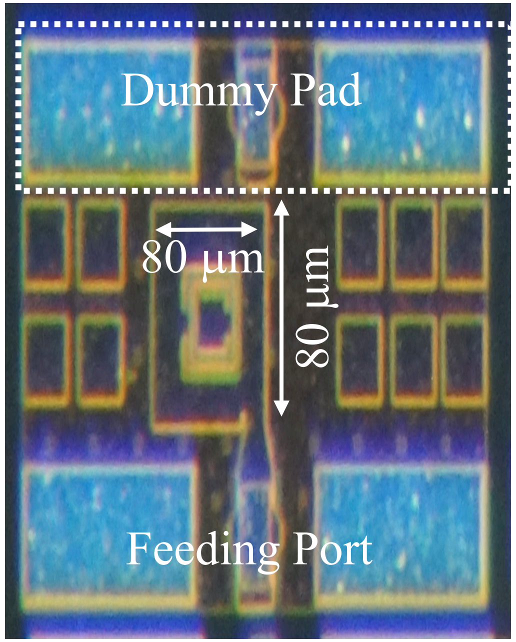
Measured Results

Frequency (GHz)	External Q-factor
207.2	142

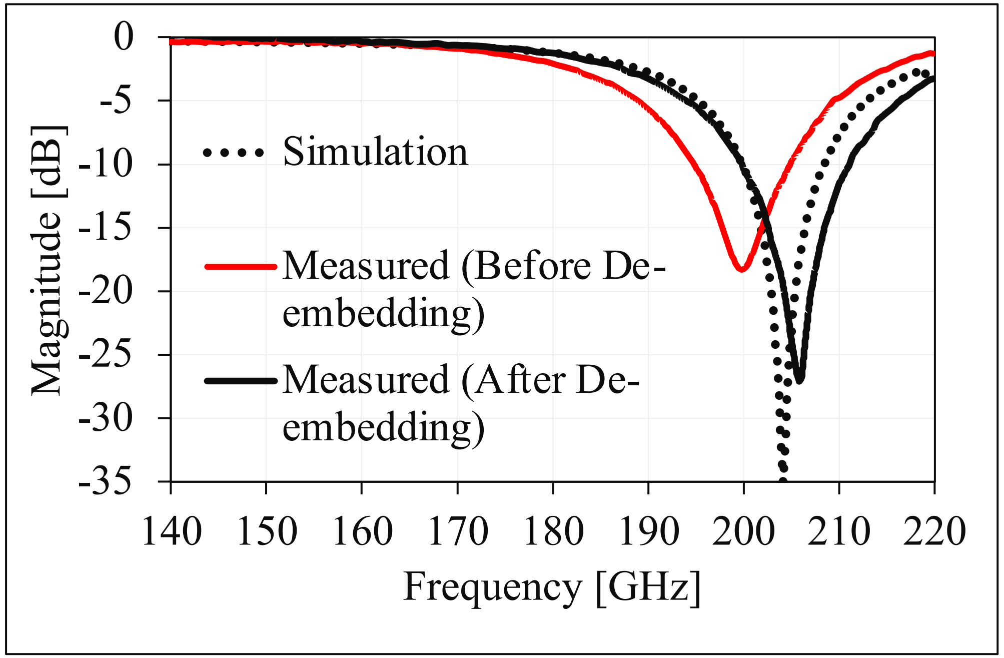
(c)

Fig. Proposed QMSIW Cavity Resonator (a) Micrograph of fabricated prototype; (b) Simulated and Measured S-parameters; (c) Measurement results of frequency and external quality factor.

Fabrication Layout of the Proposed Cavity Resonator



(a)



(b)

Measured Results

Frequency (GHz)	External Q-factor
206.3	158

(c)

Fig. Fig. Proposed QMSIW Cavity Resonator with CSRR loadings (a) Micrograph of fabricated prototype; (b) Simulated and Measured S-parameters; (c) Measurement results of frequency and external quality factor.

Summary

- ❑ Miniaturized Sub-Terahertz Band SIW cavity resonator is achieved by:
  - ➢ Taking quarter-mode of standard SIW cavity resonator
  - ➢ Employing folded ridge structure
  - ➢ Inductively loaded with CSRR resonator.
- ❑ The proposed design is fabricated in a commercial CMOS technology.
- ❑ The internal matching provided by the effective inductance from the CSRR at the resonance in the proposed SIW cavity resonator presents both the reflection coefficient and the Q-factor improvement.
- ❑ The proposed SIW cavities resonator utilizes only 2.46 % and 2.4 % area of the standard SIW designed at the same resonance.
- ❑ This miniaturized Cavity Resonator can find applications for designing high performance on-chip filters, antennas, oscillators, etc.

Thank you for your attention.

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